The Visual Word Recognition and Orthography Depth in Second Language Acquisition

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Declaration

I have read and understood The University of Edinburgh guidelines on Plagiarism and declare that this written dissertation is all my own work except where I indicate otherwise by proper use of quotes and references

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Abstract

The study investigated whether the orthographic depth of first language (L1) affects the word recognition in second language (L2) learning. Fifteen native Chinese speakers and fifteen Greek native speakers were recruited to test their English naming ability. The results suggest that the orthographic depth has an impact on the L2 learning but word familiarity also determined the naming performance in certain extent. The data can be interpreted as the supportive evidence of implicating the *Orthographic Depth Hypothesis* (ODH) on L2 learning (the original ODH mainly refers to the orthographic depth effect on L1). However, the regularity influence of spelling-to-sound rules was a very weak predictor of orthographic depth variations. The data is able to modify the strong dual route model of word recognition by providing some empirical evidence.

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1. Introduction

The purpose of the present investigation is to explore the L1 orthographic depth influence on L2 word recognition according to two key theoretical aspects. Firstly, the *Dual Route Hypothesis* (DRH) suggests a two-pathway model of word recognition including a lexical and a non-lexical route. Secondly, the *Orthographic Depth Hypothesis* (ODH) proposes that the cross-linguistic variations of the tendency to employ these two routes depending on the orthographic depth, namely the way one reader processes the sounds from the written form is affected by the directness and ambiguity of the correspondences between pronunciations and scripts of his or her L1 orthography. In addition, some studies have pointed out that cross-linguistic variations have been observed not only in the L1 literacy but also in the L2 word recognition (Erdener, & Burnham, 2005; Escudero & Wanrooij, 2010; Schwartz, Kroll, & Diaz, 2007; Vokic, 2011). The previous literatures from the perspectives of relations between orthography and phonology in both first and second language acquisition were examined to construct a theoretical research foundation.

An English naming task was designed to investigate the empirical evidence. Two languages were chosen: Greek, a shallow orthography and Chinese, an opaque orthography. Moreover, the regularity of spelling-to-sound rules and word frequency as other possible control factors were considered in the experiment. The participants carried out the English naming task in order to test their L2 word recognition ability. Naming latencies and response-accuracy rate were both calculated and analyzed. The implications and limitations of the present study are discussed in the last part of the dissertation.

2. Research Background

2.1 The Relationship between Script and Sound

Since most languages can be presented in written form, the relationships between print, word meaning and sound have been of interest to many psychologists, linguists and educators. It is obvious that the procedure of a human acquiring spoken language is very different from written language. One example is illiteracy, in which a normal person without any physical deficit knows how to speak a language, but the same individual does not have the ability to read and write. A subsequent example comes from dyslexic patients, who are unable to read and write due to a dysfunction in certain part of brain. From the earliest studies by Wernicke (1874) on dyslexia, it has been suggested that there are at least two mechanisms of accessing the meaning of printed words (as cited in Henderson, 1982): (1) a lexical pathway where the visual input is directly linked to the correspond meaning in the perceptual lexicon, and (2) a non-lexical pathway where the visual input is first translated into a series of speech codes and then used for accessing the lexical pool. The recent studies following the notion of distinction between non-lexical and lexical paths in word processing have proposed several possible components to explain the dyslexia such as phonological disability (Coltheart, 1987). Dyslexic patients with a phonological disability usually process words such as *run*, *runs*, *runner* and *running* as four different words instead of a word stem *run* with morphemes *-s*, *-ner* and *-ing*. In other words, the impairment of the phonological path of dyslexic patients causes them to utilize the alternative lexical path, which is to retrieve the meanings of *run*, *runs*, *runner* and *running* and recognize these words as four individual lexicons. This phenomenon indicates the distinction of a solely phonological pathway from lexical one in word representation (Patterson, 1977). As for normal readers, because the bound morpheme *-s*, *-ner*, and

-*ing* do not have corresponding abstract semantic representations, they are normally processed only by the phonological codes. Besides the evidence of dyslexia, another supportive evidence of multi-pathway word recognition is the capability of processing non-words. Seidenberg and McClelland (1989) conducted an experiment on English children to test their word recognition skills. Their results showed that given a previous training of sufficient corpus, the subjects were capable of pronouncing the non-words correctly based on the spelling-to-sound rules. Since the non-words do not have a lexical representation, it is logical to conclude that the procedure excluded the lexicon route. Thus, the distinction between lexical and non-lexical mechanisms was manifested by the investigation.

The notion of two different routes of processing word meaning has been used by many scholars to frame the *dual route theory* (Colthear, 1987; Forster & Chambers, 1973; Meyer, Schvaneveldt, & Ruddy 1974; Morton & Patterson 1987). Under this framework, the graphemic, lexical and phonetic representations of a word are separated and stored independently, which means that in some cases, one reader could move between graphemic form (print) and phonetic form (speech) without going through the lexical representation (see Figure 1). Specifically, route (1) (on the left side) requires the reader to activate word-specific abstract knowledge in order to keep the orthographic, semantic and phonological units inside the lexicon network connecting. Route (2) (on the right side), on the other hand, requires the reader to build up a series of spelling-to-sound rules, namely graphemic-phonemic correspondences (GPCs), by assigning each phoneme to its unique orthographic letter.

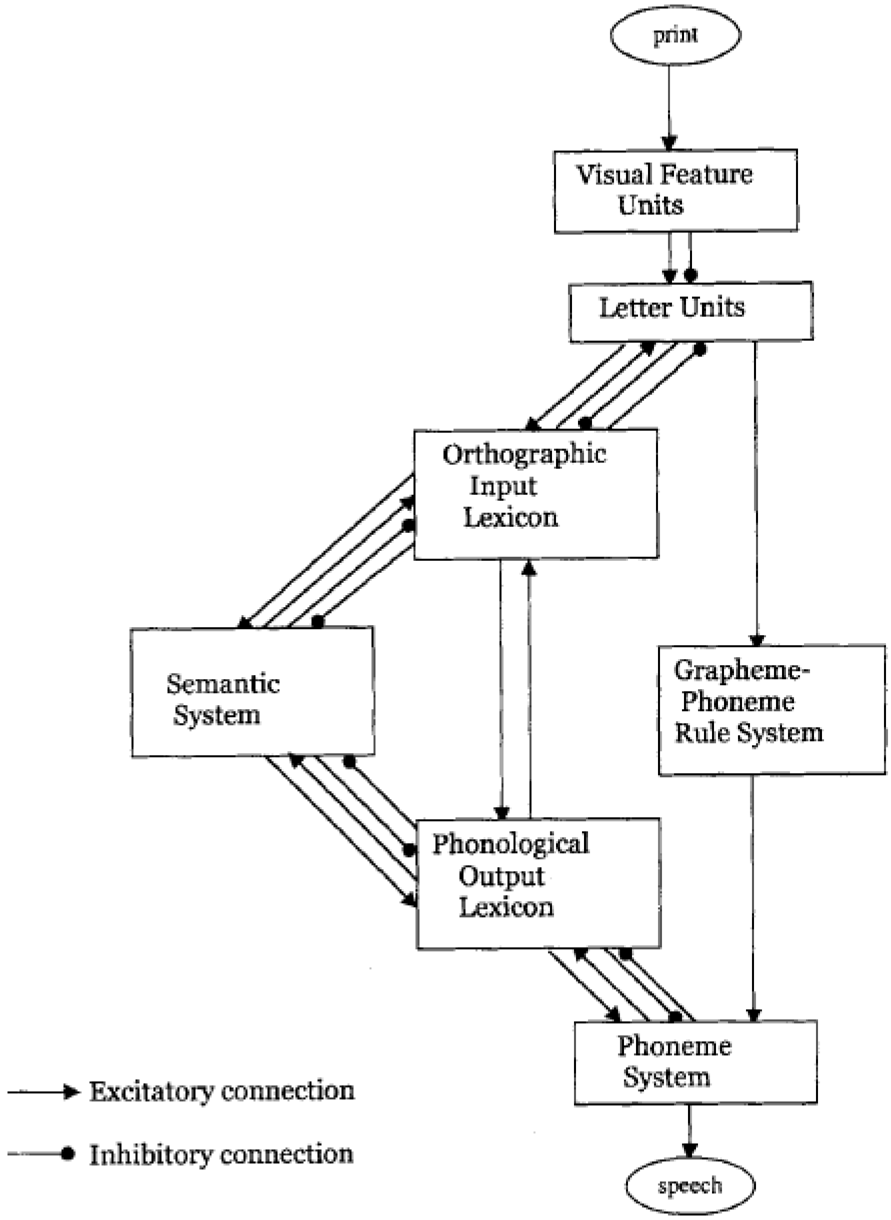


Figure 1. Dual route theory model of word recognition and reading aloud[1]

Like many theoretical models, the strong version of *dual route theory*[2] also has some problems that weaken its reliability. One of them is that the strong *dual route*

[1] The figure 1 is a dual-rout cascaded model established by Colthear, et al. (2001), which is a computational realization of *dual route theory* of word recognition and reading aloud.

[2] The term of strong *dual route theory* was used by Humphreys and Evett (1985) where they indicated the two primary criteria of strong *dual route theory*: (1) there is only one lexical and one non-lexical route in the strong version. (2) these two routes do not interact with each other. The further modified edition refers to the weak dual route theory which was termed as *dual route hypothesis* throughout this paper.

theory does not have prima facie supportive evidence of a complete non-lexical route (as route 2 in the model) in non-word recognition (Henderson, 1982; Humphreys & Evett, 1985). In some of the non-word studies, the stimuli selected were pseudohomophones (homophonic with real words) and non-homophonic non-words. The results showed that the former were responded to no slower than the latter in the lexical decision tasks, which is called the pseudohomophone effect and first indicated by Rubenstein et al. (as cited in Humphreys & Evett, 1985). The pseudohomophone effect was interpreted as supportive evidence of *dual route theory* because the lexical codes were activated in pseudohomophones recognition, which causes longer reaction time than usual non-words. However, Humphreys and Evett (1985) argued that it could also be a visual effect rather than purely the process of spelling-to-sound rules and the activation of a completely phonological route is still unclear. Therefore, the pseudohomophones effect is not eloquent for the *dual route theory*

Another drawback is that purely phonological decoding cannot be found in real word recognition. The strong *dual route theory* suggests that words with usual graphemic-phonemic associations are considered as regular words which can be processed only by the phonological route (Coltheart, 1978; Coltheart, Curtis, Atkins & Haller, 1993; Cotheart, Rastle, Perry, Langdon, & Ziegler, 2001). Any word that does not follow the usual graphemic-phonemic associations will not be recognized through the phonological route by experienced readers. Instead, one might have to activate the lexical route in order to map the correct pronunciation. Words like this are called exception words or irregular words and their ambiguous spelling regularity is due to the unidirectional links between letters and sounds. Moreover, the strong *dual route theory* predicts that regular words will be named faster and more accurately compared to irregular words because the phonological route and lexical route will violate each other in irregular word recognition. However, the *analogy theory* has been proposed as an alternative option to indicate that there must be lexical decoding in phonological processes (Glushko, 1979; Henderson, 1982; Key & Marcel, 1981). The *analogy theory* claims that minimal orthographic presentation is not single letter but letter strings composed by vowel and consonant cluster, for instance, the pattern such as *–US*T in *MUST* and *DUST*. Thus, the process of spelling-to-sound knowledge is in fact the mapping between pronunciation and its appropriate orthographic segment. Moreover, because the minimal unit of orthography is a combination of letters, the regularity of graphemic-phonemic correspondence is dependent on the consistency between the letter strings and pronunciation. A word that has a string of letter patterns that are pronounced similarly in all other word neighbors is considered a consistent word. Glushko (1979) found that regular but inconsistent words such as *WAVE* have influence from the exception words like *HAVE* because of their highly orthographic similarity, whereas regular consistent words like *WADE* will not undergo the same effect because *–ADE* is a consistent letter pattern. In other words, even the words with regular spelling-to-sound rules will be pronounced slower due to their inconsistency with other word neighbors. Therefore, the regular effect does not exist in regular-inconsistent words, which means that phonological consistency might be the primary effect in word recognition and that regularity will only take place as the compensatory strategy secondarily. Furthermore, other studies based on the analogy approach also demonstrated that consistent words were recognized faster and more accurately than the inconsistent words (McClelland & Rumelhart, 1981; Plaut, McClelland, Seidenberg & Patterson, 1996; Seidenberg, 1985; Seidenberg & McClelland, 1989). The overall point is that, according to the analogy theory, there is no non-lexical route because all the regular words are processed through orthographic and phonological representations of known words, which always involves the lexical information.

Regardless of the limitations of strong *dual rout theory*, with some further modifications, the weakened version of the modified standard model still preserves the general ideas of *dual route theory*. For example, Patterson and Morton (1985) argued that there are two senses in the spelling-to-sound correspondences; one is the one-to-one translations in which each single letter has one and only corresponding sound presentation. The second is one-to-several translations, where phonological processes are the mapping between sound and “body”, the letter strings combining consonant cluster and vowel cluster. Unlike the orthographic neighborhood as *analogy theory* suggested, the second type of spelling-to-sound sub-system is just a larger unit of letter patterns which is non-semantically mediated. Therefore, the word body does rely on the simple spelling-to-sound correspondences rather than the analogy of known words. This modification is able to explain the consistency effect mentioned in the previous section without abandoning the *dual route theory all together*. Another modification is by assuming that both non-lexical and lexical routes are both activated during word recognition, and it is only the sequence and degree of activating each route that differentiate the procedure (Henderson, 1982). For example, when processing exception words, the phonological route will first be activated. But since the phonological codes cannot correctly retrieve the pronunciation, the lexical route will then be activated as alternative strategy and cause a time delay. This effect does not exist in the regular words, which explains why the reaction time is always faster in comparison to exception words. Moreover, the weak version of *dual route theory* also emphasizes the interaction of lexical and phonological routes because some investigators have demonstrated a naming latency overlap between these two routes (Patterson & Morton, 1985). As a result, the present study only adopted the weak version of *dual rout theory* and refers to this as *dual route hypothesis* (DRH) in the following discussion.

Another important factor affecting the relationship between orthography and phonology is phonological awareness: the awareness of accessing the sound structures from oral speech (Wagner, Torgesen, Rashotte, Hecht, Barker, Burgess, Donahue, & Garon, 1997). One way to measure phonological awareness is by testing the ability of segmenting the minimal sound unit from a continuous speech string. It is believed to be the first (or at least one of the earliest) steps in the development of reading skills. In addition, because phonological awareness also develops through reading and writing, children who have higher phonological awareness outperform those with lower phonological awareness (Adams, 1990; Bradley & Bryant, 1983; Goswami, 1999; Perfetti, Beck, Bell, & Hughes, 1987). Moreover, phonological awareness is a strong predictor of other phonological processing skills such as verbal memory and speeded naming according to several cross-linguistic studies (Bruck, Genesee, & Caravolas, 1997; Hoien, Lundberg, Stanovich, & Bjaalid, 1995; Kim, Kim, & Lee, 2007; McBride-Chang, & Kail 2002; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Ziegler & Goswami, 2005; Ziegler, Bertrand, Tóth, Csépe, Reis, Faísca, Saine, Lyytinen, Vaessen, & Blomert, 2010). As Ziegler et al. (2010) pointed out "The modulation of phonological awareness by transparency is certainly a direct consequence of the reciprocal influence of phonological awareness and reading" (p.556). These studies included different orthographic languages including English, Finnish, Norwegian, Hungarian, Dutch, Portuguese, French and Chinese and Korean. Despite the fact that all the languages do not have the same orthographic system, the impact of phonological awareness on pronunciation latency and verbal fluency was observed among all the languages. Furthermore, these studies also demonstrated an orthographic variation of phonological awareness influence. The languages with regular spelling-to-sound systems, such as Finish and Hungarian, belong to high transparency orthography whereas the languages like French and English have relatively opaque orthographic systems in comparison. Chinese, known as the logographic language, can be differentiated from the alphabetic languages with its more blurry spelling-to-sound correspondences. Since Chinese characters are highly dependent on lexical information to develop reading ability, Chinese people are required to recognize, comprehend and memorize the character pool. Hence, instead of phonological awareness, orthographic awareness - the ability of connecting the links between visual symbols, phonology, and semantics, might be more essential to Chinese readers (Tan & Perfetti, 1998; Tan, Spinks, Eden, Perfetti, Siok, & Desimone, 2005). In sum, the different levels of orthographic transparency might cause different degrees of dependence upon phonological awareness. For those languages with regular sound and letter mapping association (e.g., Finish and Hungarian), phonological awareness should be stronger. On the other hand, phonological awareness is a weaker predictor of reading capacity in opaque orthographies such as Chinese.

2.2 Orthographic Depth

As previously noted, the *dual route theory* constructed a dual pathway procedure in reading scripts: the lexical route of mapping orthographic representations of words directly onto lexical entries, and the phonological route of mapping orthographic representations to sounds by graphemic-to-phonemic knowledge. A number of cross-linguistic studies have pointed out that there are different factors affecting the selection and degree of activating these two paths, and one of them is the orthographic transparency. Given the simplicity and directness of correspondences in graphemic-phonemic rules, most languages can be categorized into different depth of orthography. S*hallow orthography* refers to the languages with an isomorphic relationship between grapheme and phoneme, which means that the orthographic transparency in these languages is high. To the contrary, *deep orthography* has opaque correspondences in graphic-phonemic system because one printed letter could result in different sounds in different phonological environments.

Most European languages are alphabetic languages, in which the sounds are represented by a set of symbols. However, orthographic transparency varies in alphabetic languages. For instant, Finish and Greek are *shallow orthographies*, whereas English has relatively deeper orthographic transparency in comparison. In English, the letter '*c*' can be either pronounced as /k/ or /s/ depending on the phonological environment. The vowel system is even more complicated, for example, the letter 'o' can be pronounced as /ʊ/ in 'book' /bʊk/, /ɑ/ in 'body' /bɑdi/, /ɔ/ in 'song' /sɔŋ / and diphthong /oʊ/ in 'bold' / bold/, while letter 'a' can also be pronounced as /ɑ/ in words like 'fault' /fɑlt/ and 'bald' /bɑld/. Not only can the same letter present different phonemes in different contexts, but also the same phoneme can be represented in different letters. Therefore, the one-to-several or several-to-one connections between graphemes and phonemes makes English a deeper orthographic language. On the other hand, languages belonging to the logographic system use symbols to present an ideal or concept instead of pronunciations like alphabetic languages. The symbols directly embody the meaning whereas the phonological codes are either absent or only partially represented. Languages such as Chinese and Kanji in Japanese are the most common examples. In Chinese, although some properties of Chinese characters could provide a very limited trace of phonemes, most of them lack phonemic information. This phenomenon is reflected in the education of Chinese children learning to recognize Chinese words. It is requisite for them to acquire a phonemic spelling system[3] as primary method before they learn reading. As a consequence, compared to the alphabetic languages, pictographic languages have the most opaque orthographic transparency due to the very faint connection between symbols and pronunciations.

Since the processing of lexical and phonological mechanisms can be attributed to orthographic transparency, investigators have further hypothesized the possible influences of orthographic depth upon these two mechanisms, namely the *Orthographic Depth Hypothesis* (ODH). The ODH has proposed some predictions based on the *dual routes hypothesis* and its process variations among different orthographies (Katz & Frost, 1992). According to the ODH, the speakers of *shallow orthography* with regular graphic-phonemic correspondences rely heavily on phonological codes. Hence, one might only observe lexical codes activation during word recognition in a *deep orthography* and less activated in the shallow one. In addition, since the deeper the orthography, the more ambiguous the spelling-to-sound rules, it indicates the difficulties one might encounter in reading deep orthography. There are fruitful cross-linguistic studies demonstrating that children of *shallow orthography* outperformed children of *deep orthography*, including both European languages such as Spanish (Lopez & Gonzalez; 1999), Greek (Ellis, Natsume, Stavropoulou, Hoxhallari, Van Daal, Polyxoe, Tsipa, & Petalas, 2004; Goswami, Porpodas, & Wheelwright, 1997), German (Wimmer, & Goswami, 1994; Wimmer & Hummer, 1990), French (Goswami, Gombert, & De Barrera, 1998), and Welsh (Ellis,

[3] In Taiwan, the phonemic spelling system is *zhuyin fuhao* which is a phonemic system developed from simplified Chinese characters, whereas in mainland China, people use *pinyin*, a phonemic system composed by roman alphabet, as alternation.

& Hooper, 2001) and non-European languages like Turkish (Öney & Durgunoglu, 1997), Japanese (Seymour, Aro, & Erskine, 2003), and Hebrew (Benuck, & Peverly, 2004). These studies were interpreted as supportive evidence of ODH in three ways. First, the children of *deep orthography* (in most of the cases were English) achieved averagely lower accuracy and longer time latency in non-word naming than the children in shallow ones. One explanation supported by the ODH is that the higher error rate and longer time latencies of deep orthography children were due to reliance on lexical decoding. These children immediately activate the lexical route, and will find that non-words can only be processed by using phonological information. Thus, once they alter the strategy toward graphemic-phonemic rules, the buffer between the two routes already causes the longer time span. Secondly, the reading latency is highly affected by the word length in *shallow orthographies* (Ellis, Natsume, Stavropoulou, Hoxhallari, Van Daal, Polyxoe, Tsipa, & Petalas, 2004). Ellis et al. (2004) compared the children of Greek, English and Japanese (Hiragana and Kanji) and found out that reliance on word length is positively related to orthographic transparency. The language with the most transparency orthographic depth is Japanese Hiragana, followed by Greek, English and Kanji. These results were duplicated in the percentage of reliance upon word length in reading. In other words, the shallower the orthography, the higher the reliance of its readers on word length for naming. Because shallow orthographies require processing of words by decoding the graphic-phonemic associations, the reading order from left to right is a step-by-step procedure of mapping letters to their corresponding sounds. In contrast, Kanji was recognized with whole-word pronunciation derived from the lexical information allowing the Kanji children to read free from the restriction of word length. Finally, semantic context played an important role in *deep orthography* reading because it provides a compensatory strategy when spelling-to-sound rules fail to solve ambiguous words

(Benuck & Peverly, 2004). Another way to interpret this point is that the phonologically ambiguous words have a higher tendency to be affected by the context than the less ambiguous ones when the phonological route is not reliable. If the phonological route is reliable (as it is in the low ambiguous phonological words), then the readers will automatically reduce their reliance on lexical codes such as contextual information.

A similar orthographic depth effect was also found in adult readers. A series of studies on comparison of Serbo-Croatian and English adults have indicated a distinct variation between the activation of lexical and phonological information among different orthographic depths (Feldman & Turvey, 1983, 1984; Frost & Katz, 1989; Katz & Feldman, 1983). Serbo-Croatian, a south Slavic language spoken in the Serbia, Croatia, Bosnia and Herzegovina, and Montenegro, has very simple spelling-to-sound system with no exception rules. Evidence pointed out that when the native speakers of both English and Serbo-Croatian were assigned to the lexicon decision and naming task, the lexical code was highly activated only in English but not in Serbo-Croatian readers. Moreover, transparency of orthography can predict the speed of processing the stimuli both in printed and auditory form, in which the Serbo-Croatian native speakers had faster reaction time in the tasks (Frost & Katz, 1989). However, word frequency is not a strong factor in these experiments because there were no significant variations between high-frequency and low-frequency stimuli. Other cross-linguistic studies also displayed a similar orthographic depth effect when more deep orthographies such as Hebrew (Frost, Katz & Bentin, 1987, Geva & Siegel, 2000) and Chinese (Seidenberg, 1985) were involved. In Hebrew, the consonants are presented in letter form whereas the vowels are conveyed by small diacritical marks added to the consonants. This writing system, therefore, is considered as a deep orthography due to its ambiguity of graphemic-phonemic correspondences. Chinese, as mentioned previously, can also be classified as *deep orthography*. When the production in naming and lexical decision task of Hebrew and Chinese speakers were compared to English speakers, there was an obviously predominant activation of lexical information in visual word recognition in Hebrew and Chinese, which shows that orthographic transparency has an absolute impact on word recognition.

2.3 The Application to Second Language Acquisition

As has been demonstrated, the orthographic depth effect has been observed in a series of cross-linguistic studies in children and adults, namely in the first language (L1) acquisition dimension. In comparison to L1, the researches of orthographic depth on L2 reading are relatively novel and less abundant. However, the investigations of the L1 orthographic depth influence on L2 phonological production are particularly robust and frequently reported. The following section discussed these empirical findings as well as elaborating on some other studies focusing on the relationship between specific phonology units and their orthographical representations.

First of all, it has been demonstrated that L2 learners practice their L1 orthographic knowledge on L2 learning in speech production and literacy (Koda, 1989, 1990; Sasaki, 1991). In fact, the prior establishment through L1 literacy might benefit L2 reading ability (Swain, 1981; Holm & Dodd, 1996). An experiment conducted by Holm & Dodd (1996) investigated the English word and non-word (according to the English spelling-to-sound system) spelling and reading ability of native Chinese speakers from China and Hong Kong and native Vietnamese speakers. Among these three groups, L2 learners from Hong Kong reached the highest error rates because they have relatively low sensitivity of phonological awareness of

Roman characters, which usually sufficiently develops in English or other alphabetic language speakers. On the other hand, subjects from China and Vietnam showed some phonological awareness of Roman characters due to their phoneme system[4]. This finding suggests that phonological awareness can be developed through explicit instructions such as a phonemic spelling system which has an impact on L2 learning. Even though the transfer of L1 orthography on L2 acquisition is undeniable, the causal factors of procedural variations of different L1 orthographic backgrounds among L2 learning are still unclear. Many studies suggest that the L1 orthographic transfer could either benefit or interfere with of L2 learning, depending on the orthographic distance between L1 and L2 (Erdener, & Burnham, 2005; Escudero & Wanrooij, 2010; Schwartz, Kroll, & Diaz, 2007; Vokic, 2011). Erdener and Burnham (2005) trained Turkish and Australian participants with Spanish and Irish phonological rules, and these two groups of participants were later required to take part in a non-words task that followed Spanish and Irish phonological rules. The non-words were presented either with visual cues (with speakers' facial articulation) or orthographic cues (with printed scripts) in order to investigate which type of cues provided better information for the L2 readers to decode the speech stimuli (see further discussion in Massaro, Cohen, & Thompson, 1990). The results showed that the Turkish benefited from the regular graphemic-phonemic correspondences in Spanish non-word naming but highly inhibited by the irregular ones in Irish, whereas the English subjects had very few advantages in Spanish and no significant effect in Irish. In fact, the results were consistent with ODH in suggesting that the L2 learners from *shallow orthography* (Turkish speakers in this case) tend to highly activate the phonological route in speech, while ones with deep orthographic background (English)

[4] Both the Chinese in mainland China and Vietnamese use the spelling systems composed by roman alphabets known as *pinyin* in China and *Chu Quoc Ngu* in Vietnam.

depended more on whole-word presentation involving lexical information. In addition, both groups of participants preformed better with orthographic codes pointing out that a complete establishment of spelling-to-sound system benefits L2 learners of speech production. On the other hand, orthographic depth as interference on the phonological process has also been found in speech production (Vokic, 2011) and comprehension (Escudero, Hayes-Harb, & Mitterer, 2008; Escudero & Wanrooij, 2010), where L1 orthographic transfer in specific phonological rules were investigated. Vokic (2011) pointed out that the flap sound [ɾ] exists in both English and Spanish phonology, but it was blocked by the orthography system for the Spanish speakers in English speech production. In Spanish, the flap sound is always presented in graph <r> (e.g. lolo /loɾo/ ‘parrot’) whereas the same sound only occurs in the graphic <t>, <d> and digraphs <tt> and <dd> in English. Therefore, the Spanish subjects tended to produce [t̪] instead of [ɾ] in graphs <t>, <d> and digraphs <tt> and <dd>. However, word frequency facilitated the L2 phonological awareness and helped the L2 learners dissociate the L2 orthographic interference from graphemic-phonemic rules to quickly mapping the irregular (irrespective of Spanish) one in English. In other words, the lexical information, to a certain degree, facilitated the process of spelling to sound mapping when the L1 and L2 graphemic-phonemic rules were inconsistent. The results of this study point out a clear L1 orthographic interference on L2 speech production.

It is also worth noting that Koda (1989, 1996) described a similar notion to orthographic depth in the L1 processing skill on L2 literature called “phonological recoverability”. Phonological recoverability is referred to as the procedure of mapping written letters onto their phonological representations. L1 speakers of *deep orthography* with low phonological recoverability depend more heavily on lexical information than those of *shallow orthography* with high phonological recoverability in L2 word recognition. Koda (1990) conducted a reading comprehension task with either pronounceable or unpronounceable words on native Spanish, Arabic and Japanese learning English. The results showed that the Spanish and Arabic speakers were both significantly affected by the impairment of phonological codes in recognizing the unpronounceable words, whereas the Japanese speakers were not because of their logographic L1 language background, which causes great dependence upon visual information. Moreover, the word recognition tasks involving intrawords[5] as stimuli demonstrated that L1 alphabetic-orthographic backgrounds promote reading latencies and fluency of English intrawords recognition (Brown & Haynes, 1985; Akamatsu, 2003). For example, in Akamatsu (2003), the Chinese and Japanese subjects (with non-alphabetic L1 background) were adversely affected by the alternated case (the intrawords) whereas the Persian ones (with alphabetic L1 background) were not. Since the processing of intrawords involves mapping the letters and sounds in sequence from left to right, the mixture of lowercase and capital letters had very limited influence upon the readers who depended on the phonological route. In contrast, the readers of non-alphabetic language analyzed the printed information as a whole visual stimulus and usually paid less attention to the intraword components. Hence, it is a relative advantage for readers of alphabetical language to achieve better performance in the intraword information comprehension tasks than the readers of non-alphabetical languages.

The tendency of processing particular skills and strategies stemming from learners' L1 language backgrounds has also been observed in bilingual and trilingual studies across various tasks including consistency words (words that have

[5] Intrawords are printed information in which the lowercase and capital letters are put in sequence one by one (e.g. ExAmPlE).

the same graphic-phonemic correspondences with their neighbor) (Jared, & Kroll, 2001), homographs (Dijkstra, Grainger, & Van Heuven, 1999; Jared, & Szucs, 2002) and cognates (words sharing similar sound and form across languages) (Lemhöfer, Dijkstra, & Michel, 2004; Schwartz, Kroll, & Diaz, 2007). These studies pointed out that the bilingual are aware of the orthographic distance between their dominant and less dominant language and tended to utilize different mechanisms to recognize words from them. On the one hand, phonological decoding was highly activated by the bilingual speakers in both dominant and less dominant language depending on the orthographic and phonological properties of the languages (Jared, & Kroll, 2001; Dijkstra, Grainger, & Van Heuven, 1999; Jared, & Szucs, 2002). On the other, this lexical activation was observed to be non-selective in the cognates task (Lemhöfer, Dijkstra, & Michel, 2004; Schwartz, Kroll, & Diaz, 2007). For example, Schwartz et al. (2007) tested 16 English-Spanish bilinguals who were dominant in English with cognate words. The most striking finding is that the cognate words were named slower than the non-cognate words, presumably because the dissimilar phonology had an impact on the similar orthography. When the orthographies were dissimilar, the effect of phonological interference was not found. The results indicate the delay of naming latency in conditions of dissimilar phonology but similar orthography (e.g., *train/tren*) as the phonological code is activated first (at least in the English-Spanish bilinguals) and feed back the information to lexical routes once the there are two competing phonological presentations that need to be processed for mapping the accurately phonology to the correspond meaning.

3. The Present Study

3.1 Greek, Chinese and English Orthographic Background

As many studies have suggested, the readers of alphabetic and non-alphabetic orthographic backgrounds have various tendencies in processing phonological and lexical codes in L2 reading (Akamatsu, 1999, 2002, 2003; Brown & Haynes, 1985; Koda, 1990). Thus, the participants in the present study were native Chinese speakers (as a non-alphabetic L1 group) from Taiwan and native Greek speakers (as an alphabetic L1 group) from Greece. The naming performances of both of these groups in English (as L2) were under investigation. In order to demonstrate the research questions and predictions of the present study, it is necessary to first examine the phonemic and orthographic systems in Chinese, Greek and English.

Greek is an alphabetic language where 24 Greek letters are used to present 32 phonemes (Bakamidis & Carayannis, 1987). Greek is classified as a shallow orthography language because of its very regular graphic-phonemic rules where the written letter remains consistent across different contexts (Chitiri & Willows, 1994). Greek native speakers have better phonological awareness when compared to other deeper orthographic language such as English (Ziegler & Goswami, 2005). Moreover, the comparison studies among children of European languages showed that Greek children achieved lower error rates and shorter time latencies in fundamental reading tasks (letter recognition) than English children, which indicates that shallow orthography with consistent spelling-to-sound rules benefits the readers to develop (in childrens case) or manipulate (in second language acquisition, SLA) the phonological knowledge in word recognition (Goswami, Porpodas & Wheelwright, 1997; Seymour, Aro & Erskine, 2003). In contrast, Chinese is a non-alphabetic language and is considered as deep orthography with its logographic written system. There are six categories of forming Chinese characters: (1) *pictographs*, self-explanatory characters that were retrieved from pictures and later simplified and standardized, for example

‘木’ for “tree” and ‘日’ for “sun”; (2) *ideographs*, characters that present one concept or an abstract idea, for example the directional index such as ‘上’ for “up” and ‘下’ for “down”; (3) *compound ideographs*, with two or more ideographs to form a new concept such as combing ‘人’ for “*people*” and ‘言’ for “word” become ‘信’ for “letter”; (4) *semantic-phonetic compounds,* in this type of character, each character is combined by one semantic and one phonetic radical component (minimal unit of Chinese characters), for example, combing ‘馬’ “hours” and ‘奇’ /tʰɕi/ for ‘騎’ for “horse riding” (5) *transformed cognates,* where one cognate character is reanalyzed as another new character, for example, ‘老’ and ‘考’ were cognates refers to ‘old’, and the meaning of ‘考’ was later transformed into ‘test’ and the original meaning was lost (6) *phonetic loans,* where one character is used to represent a sound that has no written form such as ‘來’ for “wheat” has been borrowed and referred to sound /lai/ for “come” in colloquial speech (Lu, 2009). In these six categories, only the *semantic-phonetic compounds* can be recognized by phonemic representation. However, due to the very long phonetic evolution and dialects influence, many Chinese characters are unable to directly represent their original pronunciations. Hence, Chinese is considered to have an extremely opaque relationship between scripts and sounds. Some cross-linguistic studies have demonstrated that in Chinese character recognition, the lexical route plays an essential role in comparison to the phonological route (Rozin & Gleitman, 1977 as cited in Seidenberg, 1985; Leck, Weekes & Chen, 1995). For example, Leck and his colleagues demonstrated that both integrated Chinese characters (the ones with stroke components that cannot be separated, e.g., ‘及’) and compound Chinese characters (the ones are composed by at least two parts of character component, e.g., ‘剪’ which is combined by ‘前’ and ‘刀’) were primary recognized by visual codes which depend on the lexical route. Phonological decoding was only partially found in the compound type, and therefore the secondary function of the phonological route in Chinese characters was indentified.

English lies somewhere between these extremes. The English language features 40 phonemes that are presented by 26 letters including 5 vowels and 21 consonants. Unlike Greek, English spelling-to-sound rules are ambiguous, especially in vowels where the 5 vowel letters also compose 12 digraphs, 6 of which have alternative sound representation according to the phonological environment (Ellis, Natsume, Stavropoulou, Hoxhallari, Van Daal, Polyzoe, Tsipa & Petalas, 2004). The high inconsistency of spelling-to-sound rules usually causes difficulties for young native English speakers and L2 learners. Therefore, the more efficient way to learn to read English is to develop whole-word visual ability with semantic representation. Empirical evidence has indicated that both phonological and lexical codes are processed during word recognition (McCusker, Hillinger & Bias, 1981; Wagner & Torgesen, 1987). However, in comparison with Chinese, the graphic-phonemic correspondences of English are still traceable because the English alphabet letters more or less represent the pronunciations. Therefore, due to the various orthographic depths, the degree of facilitating the phonological and lexical codes among Greek, Chinese and English might differ from one to another.

3.2 Research Questions

As recent studies have mentioned, the *dual route hypothesis* suggests two possible pathways of translating written word into speech. The ODH, in addition, claims that orthographic transparency can be accounted for the cross-linguistic variations observed in word recognition. Both the dual route hypothesis and ODH are also applicable on the SLA and can be interpreted as the influence of one's L1 orthographic experience on their L2 language learning. The purpose of the present study is to further investigate the orthographic depth effect upon different L1 backgrounds of their L2 learning, especially in naming. Specifically, the L1 orthographic depth effect in SLA can be described as two aspects: (1) the L1 orthographic depth effect on the word recognition (naming) in L2 acquisition and (2) the roles of two factors on the L2 naming: the word frequency, which contributes to the lexical retrieving and the regularity of spelling-to-sound rules to the phonological decoding. If the L1 orthographic experience does affect the performance of L2 word recognition as the ODH suggests, we might assume that the variations in English naming could be revealed by testing the Greek and Chinese subjects with different L1 orthographic backgrounds. The research is intended to address its purpose to two questions:

I. Will the different L1 orthographic depth backgrounds (the L1-L2 orthographic distance) result in the different degree of phonological and lexical code activation in the L2 word recognition according to the dual route hypothesis and OHD?

II. If there are procedural variations between shallow and deep orthographic L1 backgrounds, how will the word frequency and the regularity of spelling-to-sound rules affect the naming procedure?

3.3 Regularity and Frequency Effect

If L1 orthographic transparency exacts influence on phonological and lexical utilization, the factors which might affect the phonological and lexical representations must be taken into account. It is believed that both word frequency and spelling-to-sound regularity play an important role in word recognition.

Some research has claimed that word frequency indeed might be more essential than orthographic depth in determining the facilitation of lexical and phonological codes (Forster & Chambers, 1973, Forst, Katz & Bentin, 1987; Seidenberg, 1985). Besides the independent frequency effect, the interaction between word frequency and regularity have been frequently demonstrated by other studies (Andrews, 1982; Seidenberg, 1985; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Waters & Seidenberg, 1985). In this regard, the high-frequency words are always processing visually where the semantic representation is involved during word recognition. In other words, the high-frequency words are usually retrieved from the lexical pool before the activation of phonological decoding. In the low-frequency words, on the other hand, the phonological route and lexical route are activated simultaneously. If the low-frequency words are also irregular words, the phonological codes will not be able to provide enough information and the lexical information will take over during the procedure. It is worth noting that L2 proficiency correlates significantly with L2 reading comprehension and a sufficient lexicon will facilitate word recognition processes especially in high-frequency words. Because the participants in the present study had high-intermediate levels of English proficiency, their naming performances between language groups might be different in the infrequent words only. In other words, the potential L2 proficiency effect, which might diminish the variations between Greek and Chinese, was manipulated by using different frequent English words.

Another factor that has been frequently pointed out to affect word recognition is spelling-to-sound regularity. Studies show that the deep orthography languages with very ambiguous graphic-phonemic correspondences require the readers to take an alternative strategy, namely using lexical information, in order to accurately pronounce the irregular words (Coltheart, Curtis, Atkins, & Haller, 1993). Furthermore, given the size of the orthographies (single letters or letter strings), the regularity between letters and pronunciations can be either described as regularity effects or consistency effects. Although some studies tend to distinguish the consistency effects from the regularity effects and interpret it as the supportive evidence against the *strong dual route theory* (Andrews, 1982; Jared, 2002; Jared, McRae, & Seidenberg, 1990), the present study took the standpoint of the weak version of *dual route theory* which suggesting that the regularity and consistency effects both exist in the usual graphic-phonemic correspondences. Regarding this, both the regularity and consistency deal with the same issue: the ambiguity of correspondences between letters and sounds. As a result, in the present study, in order to the avoid confounding the regularity and consistency effect, the stimuli in the experiments were counterbalanced by selecting half consistent words and half inconsistent words in both regular and irregular word sets. Moreover, we should expect to find the regularity and consistency effect under the low-frequency condition since the lexical route is not available to retrieve the pronunciations. Under the regular-consistency condition, which has no ambiguity in the graphic-phonemic correspondences, the Greek should outperform the Chinese due to their experience with phonological decoding. In contrast, the ambiguous spelling-to-sound associations in irregular-consistency, irregular-inconsistency and regular-inconsistent conditions should activate the lexical consultation. If so, the Greek participants might encounter more difficulties than the Chinese participants since the former have higher tendency to activate the phonological route. With respect to the individual regularity and consistency effect, the Greek and Chinese should both have shorter naming latencies and lower error rate on the regular condition than the irregular one (in both consistent and inconsistent pairs) as well as in the consistent condition than the inconsistent one (in both regular and irregular pairs).

3.4 Predictions

Given the logographic language background, the Chinese readers are predicted to activate the lexical route in a greater degree than the phonological one. It is also reasonable to assume that they are more efficient (or experienced) at the process of retrieving the semantic information from their lexicon. The Greek speakers, on the other hand, are more familiar with the phonological codes because the spelling-to-sound rules in Greek are regular and consistent. Since the spelling and sound is not isomorphic in the low-frequency irregular words, the Chinese speakers might react faster and make fewer errors than Greek speakers in the irregular-infrequent word naming. However, in the regular-infrequent words, the Greek speakers might outperform the Chinese speakers due to their familiarity of graphemic-to-phonemic associations. Furthermore, there will be no obvious variations in naming regular-frequent words as well as irregular-frequent words because the high-intermediate participants are supposed to be quite experienced at processing the frequent words through the lexical route. The predictions from this research can be concluded in three points as followed:

I. In the high-frequency words, the interaction of regularity, consistency and language should not be found in both the reaction times and response accuracy because of the high English proficiency of both Greek and Chinese participants.

II. In the low-frequency words, the interaction of regularity, consistency and language should be observed in both the reaction times and response accuracy since the Greek have higher tendency to employ phonological codes whereas the Chinese should have higher tendency to activate lexical codes.

III. In the low-frequency words, all of the regular words should be named faster and more accurately than the irregular words as well as consistent words than inconsistent ones by both Greek and Chinese.

By analyzing and categorizing the types of errors and the time latency, the data should indicate the possible interaction between word frequency, regularity and consistency on L2 naming.

3.5 Method

3.5.1 Participants

The present study recruited 30 postgraduate students at the University of Edinburgh. The total of 30 participants, consisting of 12 male and 18 female, were half native Greek speakers and the half native Chinese speakers. All the Greek participants are from Greece while all the Chinese participants are from Taiwan (i.e., there were no Chinese speakers from China or Hong Kong in the present study). One purpose of excluding the Chinese speakers from China and Hong Kong was to reduce the variations of English educational backgrounds between China and Taiwan, in particular, to control the possible exposure of English words with different frequency. Because the English educational textbooks vary between China and Taiwan, the frequency of one English word appearing in a particular textbook could result differently according to the book editors and educators. Another reason of selecting only the Taiwanese participants is to avoid the potential effect of different phonemic spelling systems. As noted above, since the Chinese native speakers in China use *pinyi*, there is possibility that the native Chinese speakers could be affect by the *pinyin* in their English naming performance. On the other hand, the native Chinese speakers of Taiwan use the *zhuyin fuhao*, a spelling system presented by simplified parts of Chinese characters. The Roman alphabet is always acquired for the first time when learning English, and the possible interference from L1 phonemic spelling system will not appear in the L2 in the Chinese speakers from Taiwan.

All of the participants were recruited based on the personal contact or open recruitment through the school e-mail. Each of participants was paid in 2 pounds as reward. Their mean age at the time of recording was 25. Their overall English instructional exposure was 14 years in Chinese and 10 years in Greek. None of the Chinese participants have been living in England or any other English speaking countries for more than 2 years, whereas one of the Greek participants has lived in England for more than 5 years. All of the participants had achieved a score of 6.5 on the International English Language Testing System (IELTS) or 92 on the Test of English as a Foreign Language (TOEFL) because the University of Edinburgh requires at least a score of 6.5 on IELTS or 92 on TOEFL for entry. The characteristics of each of the groups are listed in Table 1.

Table 1. Participant characteristics for each group

	Greek	Chinese
Age	25;1(1.25)	25;6(1.54)
English instructional exposure	10;9(2.87)	14;2(1.83)
Residence in English spoken countries	2;1(1.20)	1;8(0.30)

Note: the unit of measurement was mean number of years and the standard deviation in the brackets.

3.5.2 Materials

The stimuli included 80 English words categorized by word frequency, regularity and consistency (two by two by two). There were 10 words in each condition for a total of eight word groups (High-frequency, regular and consistency, high-frequency, regular and inconsistency, high-frequency, irregular and consistency, high-frequency irregular and inconsistency, low-frequency, regular and consistency, low-frequency, regular and inconsistency, low-frequency, irregular and consistency, low-frequency, irregular and inconsistency). The selection and the measurements of the stimuli were adopted from the study by Jared (2002) with slight adjustments (see appendix I). The word frequency was based on the Kucera and Francis (1967) mean frequency and Baayen et al. (1993) mean log CELEX frequency whereas the word spelling regularity was according to the graphic-to-phonemic correspondences by Coltheart, Curtis, Atkins, & Haller (1993) (all as cited in Jared, 2002). The word consistency was also adopted from Jared (2002)'s study calculated by comparing the word and its word neighbors listed in Kucera and Francis (1967) data.

3.5.3 Procedure

The experiment was conducted in the perception lab at the University of Edinburgh. The whole experiment took about 15 minutes and participants were tested individually. Before the main experiment, all participants were first required to fill out a questionnaire of their English learning experience and some relevant personal information (e.g., gender and age). There was a practice section including 8 examples in the beginning to ensure the subjects were familiar with the naming task. During the experiment, the subjects were presented with 80 English words on the screen which were equally distributed into two blocks (block A and block B) according to frequency and spelling-to-sound regularity. In other words, there were 5 words of each group per block: frequent-regular-consistent, frequent-regular-inconsistent, frequent-irregular-consistent, frequent-irregular-inconsistent, infrequent-regular-consistent, infrequent-regular-inconsistent, infrequent-irregular-consistent and infrequent-irregular-inconsistent. In each block, the order of 40 trails was randomly selected and half of the participants were tested in block A followed by block B whereas the other half had the inverse sequence. There was also a 2 minute break between two blocks.

The words were presented in black lowercase letters with a white background. Each slide of words was automatically changed to the next one once the computer received the speech input from the microphone connected to a voice-activated program. The participants were instructed to read aloud the word they see on the screen as quickly and accurately as possible. The response of pronouncing the word on the screen and the reaction time were recorded and measured in milliseconds. Furthermore, recording was judged by one native English speaker in order to mark the accuracy of the performance and the wrong pronunciations were counted as errors.

4. Results and Discussion

4.1 Results

The analysis aimed to examine the L1 orthographic effect on L2 naming by manipulating the word frequency and spelling-to-sound regularity (including regularity and consistency). The data was analyzing using a three way mixed Analysis of Variance (ANOVA) with within subject factors frequency, regularity and consistency; and between subjects factor language. Each variable had two levels and the design was a two by tow by two by two matrix. The mean of reaction times and response-accuracy rates of Chinese and Greek participants for the different conditions are listed in Table 2.

Table 2. The mean reaction times in millisecond[6] and response-error in percentage for Chinese and Greek under all conditions

	Language			
	Chinese		Greek	
Stimulus	RT (SD)	Error rate (SD)	RT (SD)	Error rate (SD)
HF/R/C	661.07 (93.09)	4.4% (0.05)	566.76 (108.02)	2.0% (0.06)
HF/R/IC	679.18 (126.40)	1.1% (0.03)	544.40 (78.96)	4.6% (0.06)
HF/IR/C	679.62 (109.60)	1.1% (0.03)	563.23 (87.43)	1.3% (0.04)
HF/IR/IC	643.71 (91.55)	3.3% (0.05)	566.75 (111.04)	2.0% (0.04)
LF/R/C	731.12(122.62)	11.2% (0.09)	608.01 (105.44)	16.7% (0.10)
LF/R/IC	770.00 (131.80)	18.1% (0.09)	603.90 (103.79)	27.5% (0.13)
LF/IR/C	722.51 (113.42)	15.6% (0.18)	564.26 (109.76)	14.5% (.016)
LF/IR/IC	778.30(160.14)	19.0%(0.18)	5614.56(138.85)	22.4% (0.09)

Note: HF= High-frequency, LF= Low-frequency; R= Regular, IR= Irregular; C= Consistency, IC= Inconsistency; RT= Reaction time; SD= Standard deviation.

4.1.1 Reaction time

The reaction time data eliminated the incorrect responses including technical errors (the unclear recording due to the technical problems), mispronunciation and the incorrect pronunciation. Mispronunciation was based on the first pronunciation given, which means that even if the second pronunciation (self-correction) was correct, the

[6] The units of reaction time and error rate were eliminated in the following analysis.

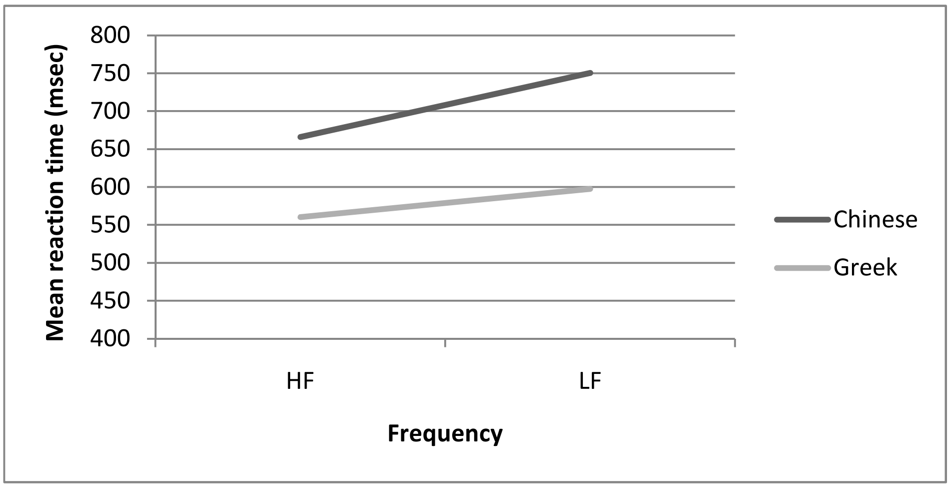
data were still excluded. The incorrect pronunciation was judged by one native English speaker, and was defined as when the phonological representation was incorrectly produced by the subjects.

The data indicated no four-way interaction of language, frequency, regularity and consistency [$F (1, 28) = 0.41$, $p>.05$]. With regards to the three-way interaction, there was only a three-way interaction among language, frequency and consistency reached the significance [$F (1, 28) = 7.66$, $p<.05$], and the rest of the combinations was not significant.

The main effect of language factor was statistically significant [$F (1, 28) =9.78$, $p<.05$] in overall L2 naming performance by participants, which indicated the L1 background was an important effect on L2 naming performance. The subjects mean reaction times was 712.27 millisecond (SD= 52.54) in Chinese and 578.98 millisecond (SD= 27.10) demonstrated the Greek participants had shorter time latencies than the Chinese in the overall average among six conditions.

Word frequency was statistically significant [$F (1, 28) =32.05$, $P<.01$], indicating that participants were affected by the word familiarity when naming the English words, in which the low-frequency words (M= 674.08, SD= 23.26) were named slower that the high-frequency words (M= 613.10, SD= 19.43). The two-way interaction of language and frequency also reached significance [$F (1, 28) = 4.30$, $P<.05$], where the high-frequency words were named faster by Greek participant (M= 560.29, SD= 23.80) than Chinese (M= 665.90, SD=30.72) as well as in the low-frequency words (M= 597.68, SD= 28.49 in Greek vs. M=750.47, SD=36.78 in Chinese) (see the comparisons in Figure 2).

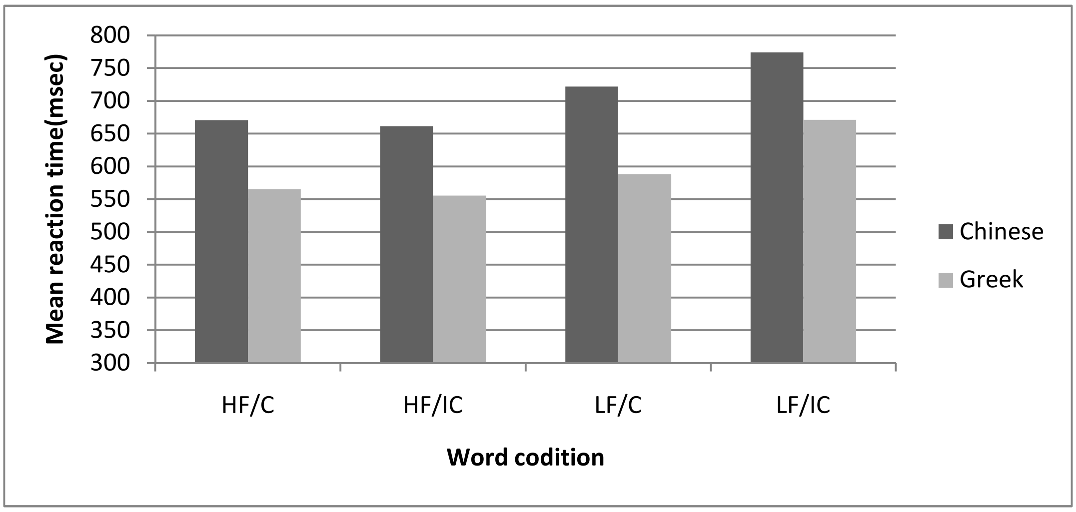
Figure 2. The mean reaction time in millisecond of high and low frequency words in Greek and Chinese participants.



On the other hand, the data did not demonstrate the regularity effect [F (1, 28) = 0.25, p>.05] as well as the two-way interaction of language and regularity which also did not reach the significance [F (1, 28) = 0.01, p>.05]. Hence, the regularity effect was not found in neither high-frequency nor low-frequency words of Chinese and Greek's naming production. The data also displayed the absence of single consistency influence [F (1, 28) = 1.80, p>.05] and the two-way interaction of consistency and language [F (1, 28) = 0.41, p>.05]. There was no two-way interaction of frequency and regularity [F (1, 28) = 0.48, p>.05], but the two-way interaction of frequency and consistency was significant [F (1, 28) = 9.18, p<.05], which the high-frequency words reached shorter naming latencies than low-frequency words in both consistency (M= 617.67, SD= 19.25 in high-frequency words vs. M= 656.47, SD= 22.81 in low-frequency words) and inconsistency conditions (M= 608.51, SD= 20.47 in high-frequency words vs. M= 691.68, SD= 26.45 in low-frequency words). In sum, among these four variables (language, frequency, regularity and language), only the effect of language, frequency and the two-way interaction of frequency and language, and frequency and consistency was found whereas the rest of the single or multi-way interaction of frequency, regularity, consistency and language was not observed in the data.

The two-way interaction of languages frequency and consistency under different L1 background were further examined using planned comparisons. The data indicates that the two-way interaction of frequency and consistency was significantly more pronounced in the Chinese [$F(1, 28) = 7.52$, $p<.005$] production in comparison to the Greek [$F(1, 28) = 3.09$, $p<.05$]. Moreover, the influence of language was significant in only the low-frequency consistency [$F(1, 28) = 8.97$, $p<.005$] and low-frequency inconsistency words [$F(1, 28) = 9.72$, $p<.005$] but not in the high-frequency consistency [$F(1, 28) = 1.64$, $p>.05$] and high-frequency inconsistency [$F(1, 28) =1.45$, $p>.05$]. The data also illustrated that the naming latencies of Greek participants were shorter than those of Chinese in all the conditions (see in Figure 3).

Figure 3. The mean reaction time in millisecond of Chinese and Greek under different two-way interaction of frequency and consistency.



4.1.2 Response accuracy

Response accuracy was calculated by adding the number of mispronunciations and the incorrect pronunciations, and then dividing by the total number of stimuli.

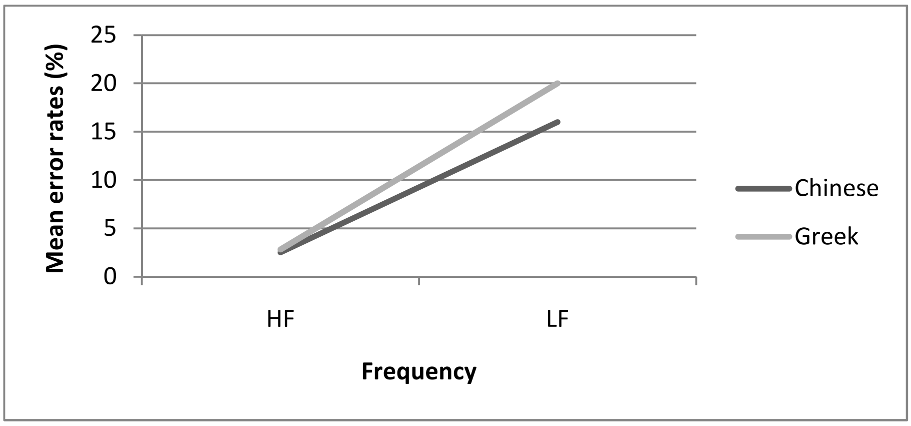
Mispronunciations were the responses which were incorrect at the first reaction, but correct at the second time (the self-correction). Technical errors were excluded.

The data indicated the absence of four-way interaction of all the factors was not found [F (1, 28) =0.67, p>.05]. The only significant three-way interaction among all the factors was the one of frequency, consistency and language [F (1, 28) =6.18, p<.05], whereas the other three-way interactions were not reached the significance.

The data also displayed no L1 influence in the overall L2 naming performance because the p-value was not significant [F (1, 28) = 0.94, p>.05]. The language participants mean error rate were 9.2 (SD= 0.11) in Chinese and 11.5 (SD= 0.12) in Greek.

The high-frequency words (M= 2.5, SD= 0.01) were named significantly more correctly than the low-frequency words (M= 18.2, SD= 0.02) [F (1, 28) = 89.844, p<.00001]. Furthermore, the two-way interaction of language and frequency also achieved the significance [F (1, 28) =5.81, p<.05]. The Chinese and Greek participants had lower error rates in the high-frequency condition (M=2.5, SD=0.01 in Chinese; M= 2.8, SD= 0.01 in Greek) than the low-frequency (M=16, SD= 0.03 in Chinese; M= 20, SD= 0.02 in Greek) (see the comparisons in Figure 4).

Figure 4. The mean error rate percentage in high and low frequency words of Greek and Chinese participants

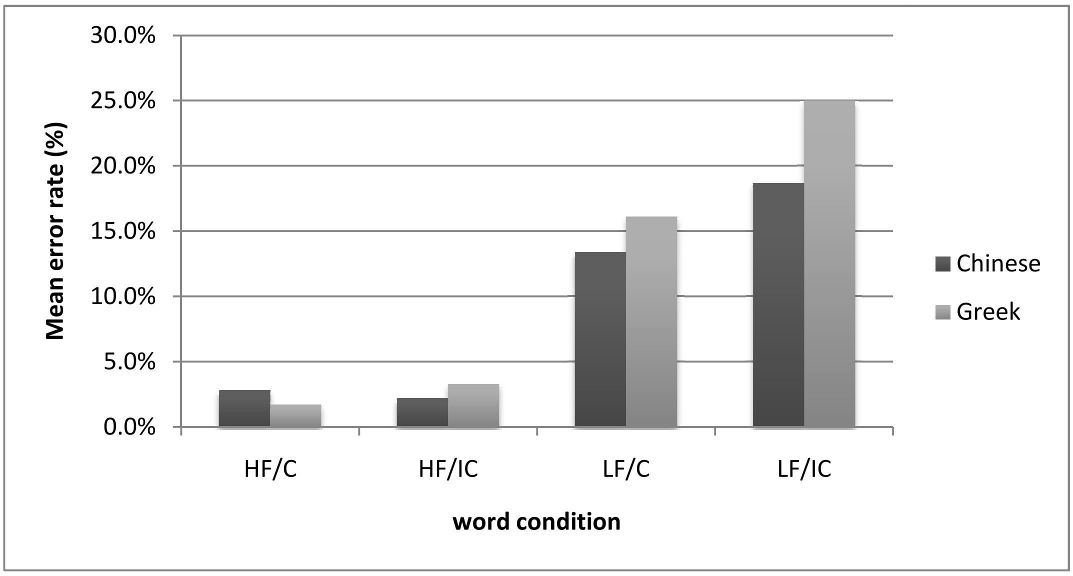


The regularity influence was not found in the error rate [F (1, 28) =0.2, p>.05], as well as the two-way interaction with language [F (1, 28) =1.47, p>.05], indicating the spelling regularity of English words does not profound any impact on the naming performance. With respect to consistency influence, the data demonstrates the significance [F (1, 28) =3.36, p<.05], which the consistency words were named more correctly (M= 8.4, SD= 0.01) then the inconsistency words (M= 12.3, SD= 0.01). The two-way interaction of consistency and language also reached the significance [F (1, 28) =7.36, p>.05], which the Greek participants had lower error rates than Chinese participants in the consistency (M= 8.1, SD= 0.01 in Greek vs. M= 8.4, SD= 0.01 in Chinese) words but had higher error rates in the inconsistency ones (M= 14.2, SD= 0.02 in Greek vs. M= 10.4, SD= 0.01 in Chinese). There was a two-way interaction of frequency and consistency influence [F (1, 28) = 9.13, p<.05], which the high-frequency words reached lower error rates than the low-frequency words in both consistency (M= 2.2, SD= 0.01 in high-frequency words vs. M= 14.5, SD= 0.02 in low-frequency words) and inconsistency conditions (M= 2.8, SD= .010 in high-frequency words vs. M= 21.8, SD= 0.02 in low-frequency words). As to the two-way interaction of frequency and regularity [F (1, 28) =0.06, p>.05], and regularity and consistency [F (1, 28) =0.06, p>.05] were not observed in the data. In summary, the individual influence of language, frequency and consistency were significant as well as the two-way interaction of frequency and language, consistency and language, and frequency and consistency.

Similar to the analyzing of reaction times, a one way ANOVA was used to investigate the language variations in the two-way interaction of consistency and frequency. The data illustrated the two-way interaction of consistency and frequency was statistically significant in Greek’s production [F (1, 28) =7.23, p<.05] but not in

Chinese's production. [F (1, 28) =2.64, p<.05]. In addition, the language was a significant factor in the conditions of low-frequency and consistency [F (1, 28) =5.74, p<.05] , and low-frequency inconsistency words [F (1, 28) =7.04, p<.05], where the as the Chinese participants had lower error rates in comparison with the Greek participants in the both conditions (M= 13.4, SD= 0.15 vs. M=16.1, SD= 0.76 in the low-frequency and consistency condition; M= 18.6, SD= 0.12 vs. M= 25.0, SD= 0.10 in the low-frequency and inconsistency condition). On the other hand, the language was not a significant factor in the high-frequency and consistency words [F (1, 28) =0.64, p>.05], and the high-frequency and inconsistency words [F (1, 28) =0.64, p>.05] (see the comparisons in Figure 5)

Figure 5. The mean error rate percentage of Chinese and Greek under conditions of frequency and consistency.



4.2 Discussion

The analysis intended to examine whether the different orthographic depth (L1-L2 orthographic distance) affects L2 naming and causes different degree of phonological and lexical routes activation during the procedure. The word frequency and the regularity of spelling-to-sound principles were controlled in the experiment.

However, the results in the present study did not completely back up the predictions by the ODH and *dual route hypothesis*.

In summary, L1 background variations were found in the overall reaction time and response-accuracy rate between Greek and Chinese, although they were not found in the high-frequency condition in the planned comparisons in both reaction time and response accuracy. Moreover, the frequency effect was found in the reaction times and response accuracy, indicating its importance in L2 naming. On the other hand, the regularity effect was not observed in the reaction time and response accuracy, whereas the consistency influence was only found in the response accuracy. In other words, the lower error rate of naming was, to a certain extent, determined by the consistency of spelling-to-sound principles while the reaction time was not.

The first prediction claimed that there should not be a significant interaction of regularity and consistency between native Greek and Chinese speakers' naming latencies and response accuracy of high-frequency words and the variations in production should only result from the overall English proficiency of the participants. In addition, study by Laufer and Nation (1995) on 22 participants learning English as second language pointed out that the word frequency is a valid indicator of language proficiency. Since the data in the present study indicates no language variation in the high-frequency words, it is reasonable to conclude that both the Greek and Chinese participants have similar English proficiency. On the other hand, as the *dual route hypothesis* suggested, the high-frequency words are supposed to be processed faster than the low-frequency words because in the former lexical knowledge is easier used to retrieve information from the lexicon than in the latter. The significance of the frequency effect also confirms an interesting phenomenon which has been frequently demonstrated in many other word recognition studies. Baron and Strawson (1976) distinguished the reading as logographic (word specific) and analytic decoding processes and suggested that the tendency of activating these two procedures is related to the types of orthography. The distinction of two-way decoding is compatible with the dual route hypothesis where the logographic decoding process can be referred as the lexical route and the analytic one as phonological route. Furthermore, in a study of word recognition using Chinese and English participants, Seidenberg (1985) pointed out that the distinction between logographic and analytic decoding processes greatly correlates with word frequency. Specifically, the high-frequency words in English are recognized logographically, similarly to Chinese, whereas low-frequency English words are recognized analytically. Therefore, the process of recognizing the high-frequency words, which is based on the visual association between meaning and printed form, does not require the consultation of phonological information. One of the implications of this is that even though there has been a strong claim of reliance of phonological codes in reading orthographies with direct and regular spelling-to-sound principles, this reliance cannot be accounted for by the high-frequency words. In other words, the predictability of orthographic transparency in naming latencies diminishes when the words become more frequent. The results of present study also indicate that word frequency is the strongest factor among others in the cross-linguistic comparison including L1 orthographic backgrounds of alphabetic languages such as Greek and logographic ones such as Chinese. Thus, the Greek and Chinese participants showed no significant variation in naming high-frequency words whether the high-frequency word had regular or irregular graphemic-phonemic correspondences. It is plausible to conclude that the orthographic depth effect as a predictor of indicating the processing speed and accuracy variation between deep and shallow orthographies is no longer predictable once word frequency is involved. That is, the effectiveness of word pronunciation in the diachronic process might be modulated in a greater degree by the word familiarity.

The stimuli in the present study were distinguished into regular words and irregular words according to whether the words generate conflict in the phonemic level that might cause an incorrect response by readers. The results indicate the absence of regularity effect in response accuracy and reaction time. Moreover, the two-way interaction between regularity and language was not significant in both naming latencies and response accuracy. In other words, the spelling regularity effect was not apparent in the present study. That is, the regular words should be processed faster than the irregular words because the dual pathways are both available for processing the regular ones whereas these pathways will clash in the procedure of irregular ones. On the other hand, as mentioned previously, the regularity of graphic-phonemic correspondences can result not only in the spelling regularity, but also consistency depending on the size of letter strings. As the *dual route hypothesis* suggests, the 'body' system of graphic-phonemic principles is capable of explaining the consistency effect by proposing a one-to-several translation. In fact, the processes of one-to-one translation and one-to-several translation as two different strategies were sometimes confounded as the same in some studies (Jared, 2002). In most of experiments, because the irregular words were also inconsistent words, the regularity effect was treated as a consistent effect and the usage of spelling-to-sound knowledge was not identified. On the other hand, since the regular words in most studies were consistent words, the regular effect was not distinguished from consistency effect as well. As a result, the appropriate way to identify the sole regularity effect or consistency effect rather than the interaction between them is to treat regularity and consistency as two factors and compare naming performance separately. The present study intended to identify the regularity and consistency effect by finding the shorter naming latencies and lower error rate in the consistent words compared to the inconsistent ones and in the regular words compared to the irregular ones in both Chinese and Greek participant’s performance. The results of the analysis displayed a definite consistency effect in the response accuracy, which the consistency words were named more correctly than the inconsistency words. However, the regularity effect was only found in response accuracy as well as the naming latency. In other words, the consistency effect observed in the response accuracy provides strong evidence of the one-to-several translation in processing graphemic-phonemic correspondence. Since only the consistency effect was observed in the data, it is reasonable to assume that the consistency effect is a stronger predictor for response accuracy of low-frequency words. Moreover, to the learners of English as second language, it is more efficient to adopt letter clusters as minimal units rather than the single letters to map the phonological representations. One of the points that can be drawn from data is that the regularity effect is not equal to the consistency effect and they cause unnecessary confounds. Another point is that the ambiguous spelling-to-sound principles will affect the response-accuracy rate in the basic unite of a series letter strings when the pathway of retrieving the lexical information from the lexicon is not available. Therefore, the same effect will be less conspicuous in naming the high- frequency words.

According to the second prediction, there should be a significant variation of the interaction between regularity and consistency in the low-frequency words in naming latency and response accuracy by the Greek and Chinese because the transparent orthographic background of Greek participants enables them to apply the same word recognition process in naming the low-frequent words whereas the Chinese participants tend to rely highly on the lexical decoding. The data only indicates the interaction of frequency and consistency, whereas the regularity effect was not found. The analysis by the planned comparisons revealed that the L1 backgrounds affected low-frequency words naming performance in both reaction time and response accuracy. In addition, Greek participants had shorter reaction time latencies and lower error rates than the Chinese when naming the consistency and inconsistency low-frequency words. The superiority of Greek participants in consistency low-frequency words can be interpreted as supportive evidence of ODH. Because the consistency words can be effectively recognized by simply practicing the regular spelling-to-sound rules, the Greek participants, who are very experienced of the phonological coding, were favored by their L1 aphetic-orthographic knowledge. The Chinese participants, on the other hand, were also influenced by their L1 orthographic backgrounds and did not have sufficient experiences of processing phonological information which was reflected in the slower reaction time in comparison to the Greek participants. To the contrary, in the low-frequency inconsistency word naming , the Chinese were expected to do better than the Greek due to a higher reliance on (or greater familiarity with) lexical codes. This can facilitate the naming procedure when the phonological path is unavailable. The planned comparisons of infrequent and inconsistent words demonstrated the impact of L1 backgrounds in both the reaction time and response accuracy. The Chinese participants achieved higher accuracy rates than the Greek. However, native Greek speakers had lower reaction times than Chinese ones. One explanation to reinterpret this outcome is that the buffer time of the interaction of phonological and lexical routes might cause a delay of latency. In the processing of low-frequent inconsistency words, since the phonological route was blocked due to the ambiguous spelling-to-sound correspondences, the lexical route needed to be activated in order to complete the word recognition procedure. It seems reasonable to hypothesize that the Greek participants might only recognize the infrequent inconsistency words through the phonological route which allowed them to react faster during naming. Nevertheless, the regular spelling-to-sound correspondences were incapable of retrieving the correct lexical knowledge. Therefore, the native Greek speakers were able to achieve faster reaction times but failed to name the infrequent inconsistency words correctly. To the contrary, the native Chinese speakers activated the lexical route for naming the infrequent inconsistency English words as a similar procedure to the one used when recognizing Chinese characters. To activate both the phonological and lexical routes involves more cognitive skills, which could cause longer time latency and explain the slower reaction time but higher response accuracy rate in Chinese's production.

5. General Discussion

The present study was designed to inspect how and to what extent L1 orthographies influence the L2 word recognition. In particular, the presupposition of the empirical study assumed that readers usually tend to apply their L1 orthographic depth backgrounds to their L2 reading. The results revealed that not only the L1-L2 orthographic distance but also the accessibility of lexical and phonological routes in processing the L2 has an impact on naming performance. As discussed previously, the outcomes can be summarized in three main points:

I. The Chinese and Greek participants showed no significant difference in the reaction time and response-accuracy rate in naming the high-frequency words.

II. The influence of word frequency was significantly found, whereas the high-frequency words were named faster and more accurately than the low-frequency ones.

III. In the low-frequent words, the Greek participants reacted faster than the Chinese participants in both consistency and inconsistency word conditions. The Chinese participants scored more accurately than the Greek participants in the inconsistency word condition, but less accurately in the consistency word condition.

IV. Both the Chinese and Greek participants were able to read the consistent words more accurately than the inconsistent ones, but the faster reaction in naming the consistency words according to the prediction in comparison with inconsistency words was not found.

The importance of these outcomes above is identifying the tendency of lexical and phonological activations of readers from different L1 orthographic backgrounds. The L1 orthographic vitiations observed in the low-frequency conditions are the supportive evidence of *dual route hypothesis* and ODH on L2 naming. Due to the L1-L2 distance, the Greek and Chinese participants showed in different tendencies and priorities of activating the dual routes in processing of words either with regular or irregular spelling-to-sound principles.

There are several implications from the present study. Firstly, the lack of L1 backgrounds difference in the high-frequency not only demonstrates the resemblance of English proficiency of two language groups, but also the primary activation of lexical information and the subsequent activation of phonological information decoding . The Chinese and Greek readers differentiated the high and low frequency English stimuli and processed them with different mechanisms. Because the high-frequency English words are usually accessed through logographic representations, visual familiarity is considered as the primary strategy. Thus, both Chinese and Greek exerted lexical decoding in naming the high-frequency words, which diminishes the influence of regularity of spelling-to-sound rules driven by the phonological route.

Secondly, L1 alphabetic experience, to a certain extent, promotes L2 naming latencies that have been demonstrated in some other studies. In fact, the finding also accounts for the validity of the ODH to the L2 word recognition. The Greek subjects in the present study benefited from their alphabetic L1 experience when practicing similar phonological decoding on naming regularity English words. Nevertheless, the words with ambiguous graphic-phonemic associations did not give the Greek participants any advantage. Using the regular spelling-to-sound principles allowed the Greek subjects to name the consistent words faster but incorrectly. The Chinese participants who are more familiar with lexical decoding, on the other hand, did not have the advantage of effectively processing the phonological information. Since to activate both the phonological and lexical routes requires more cognitive skills, the Chinese subjects needed more time to recognize the inconsistent words, but successfully mapped the correct phonological representations in the end. This phenomenon explains the fact that Chinese participants had wilder procedural variations than Greek because of their deep L1 orthographic background, which involves more cognitive skills to accomplish the dual route activation.

The third implication is that the qualitative differences (response accuracy) and quantitative differences (reaction times) speak for different perspectives of dual routes in naming procedures. In fact, Frost et al. (1987) argued that most of the studies on L2 word recognition have an inappropriate interpretation of using the time course of coding speed as the only determinant of activating either the phonological or lexical route. However, the time course, mainly the time delay, can also reveal the time buffer caused by the interaction between lexical and phonological routes. On the other hand, the quantitative differences describe the efficiency of lexical and phonological mechanisms, which provides essential information on how the reader employs the dual strategies when there is conflict in between. It should be also pointed out that the qualitative and quantitative differences should be seen as complementary to each other when interpreting the data. After all, there is no suitable measurement to indicate whether one reader actually tried to read as fast as he could without considering the accuracy or vice versa, especially in L2 word recognition when the language intuition is absent. In other words, the tendency of either naming a word fast or correctly might attribute to the cultural backgrounds of Greek and Chinese participants, so the qualitative and quantitative differences should be carefully counterbalanced in analysis.

Additionally, it is easy to confound the regularity effect with the consistency effect, which should be cautiously distinguished. In fact, the results of the present study indicate that the consistency of graphic-phonemic correspondences was sustained and had a more profound impact on L2 word recognition than the regularity effect because neither the single regularity effect nor the two-way interaction with consistency effect was found in the data. Furthermore, the results also displayed a more efficient way of mapping the spelling-to-sound association (at least in English), which is to use letter clusters as a minimal graphic unit.

Last but not the least, the speakers of shallow orthography have more sensitive phonological awareness, which can be also observed on their L2 performance. This implication comes from the comparison between alphabetic and logographic language which concludes that the speakers of alphabetic language have a greater degree of phonological awareness than the logographic ones. The variations of L2 naming performance between different L1 orthographies have been demonstrated in several studies as mentioned in the research background section ((Bruck, Genesee, & Caravolas, 1997; Hoien, Lundberg, Stanovich, & Bjaalid, 1995; Kim, Kim, & Lee, 2007; McBride-Chang, & Kail 2002; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Ziegler & Goswami, 2005; Ziegler, Bertrand, Tóth, Csépe, Reis, Faísca, Saine, Lyytinen, Vaessen, & Blomert, 2010). All of the evidence has point to the fact that phonological awareness plays an important role in naming speed and is highly correlative to orthographic transparency where the deeper the orthography, the less the phonological awareness. In the present study, the shorter time course of Greek's performance can be interpreted as the advantage of their high sensitivity of phonological awareness. Although English has opaque orthography, the Greek participants somehow were able to promote their phonological awareness on the English naming performance.

Regarding to the limitations in the present study, one of them is that it is very difficult to select an alphabetic language that has no possible alphabetic interference from English. The orthography such as Greek or Cyrillic systems has a small portion of alphabetic overlap with Roman systems like English. In addition, these overlapping alphabets have caused difficulties and ambiguities in the readers (Feldman, 1992; Feldman & Turvey, 1983; Lukatela, Turvey, Feldman, Carello & Katz, 1989). Specifically, studies of the bi-alphabetic readers of Serbo-Croatian, in which orthography can be presented either by Roman or Cyrillic letters, showed longer latencies on words with ambiguous spelling-to-sound translation (words with the overlapping alphabets) than with unique alphabet translation (words with non-overlapping alphabets). As a consequence, the interference of the ambiguous alphabets between two orthographies was clearly indentified. On the other hand, it is difficult to find another alphabetic orthography due to the lack of sufficient participants. Ideal participants of alphabetic orthographies such as Santhali (a language belongs to subfamily of Austiro-Asiatic and spoken in India, Bangladesh, Nepal and Bhutan) or Neo-Tifinagh (the writing system of Berber language spoken by Berber in area like Morocco) are extremely difficult to recruit.

Some other limitations were due to the limited time which can be modified or improved in a future follow-up study. First of all, there was not an a priori test of L1 word recognition ability of the participants in the present study. The Chinese and Greek subjects were assumed to have approximately equal word recognition ability when participating in the experiment. Their L2 word recognition skills were evaluated by their English proficiency test such as IELTS or TOEFL and the lack of L1 background influence in the high-frequency conditions, whereas their L1 word recognition skills had not been tested. Since the naming performances of high-frequency words were assumed to attribute to the overall English proficiency of subjects, it can be confirmed by comparing the performance pattern of L1 and L2 naming. Hence, a more firm conclusion can be drawn down as to whether the superiority of Greek participants in naming latencies was due to their better overall English proficiency or other possible factors; and whether the lower error rate of Chinese participants in response accuracy was because of their averagely better cognitive skills such as memory span. Second, the naming task only represented partial evidence (no matter if the evidence is supportive or not) of *dual route hypothesis* and ODH. Many similar studies also investigated word recognition capability by lexicon judgment and non-words naming. Since the procedure of word recognition is very complicated and usually involves many different cognitive skills and potential factors such as word frequency or contextual influence, these tests will be able to provide some further descriptions of the procedure in L2 word recognition.

Finally, there was no native speaker control group in the study. Although it is reasonable to suppose that the native English should reach the lowest error rate and fastest reaction time, there might be variations in the error pattern which could reveal some extra information that was not found in the present study. After all, the data from the control group can be used as a reference as well as the predictors of Standard English naming performance.

In light of these limitations, future studies should be conducted in order to depict a clearer picture of how L1 orthographic depth affects L2 word recognition. Then, with more firm identifiers of procedural patterns being revealed, not only will we have proper judgments of theoretical models, but a better guideline to point out further research into other potential factors that might favor these models.

6. Conclusion

The present study explored the validity of the L1 orthographic depth influence on the L2 reading. Four conclusions were drawn from this experiment. First of all, the variations of onset-activation and interaction between phonological and lexical routes observed in the naming performance were due to the orthographic transparency. Secondly, the ODH is capable of being applied to not only L1 reading but also L2 word recognition performance, which is profoundly affected by the L1-L2 orthographic distance. In other words, the L1 orthographic experience may induce or reduce the L2 naming process depending on the L1-L2 orthographic distance. Third, familiarity of words facilitates lexical decoding, which was found in the high-frequency and low-frequency words comparison. Finally, people learning English as second language tend to process English letters in clusters rather than single graphic symbols, which accounts for a stronger consistency effect in naming latencies and response accuracy.

Given that the present study has demonstrated the importance of L1 orthographic influence, more cross-linguistic studies and more types of orthography should be examined in the future. Moreover, word recognition as the very first step of exploring the reading skills should be extended in the research dimension by investigating the L1 orthographic influence on lexical decision, intraword or non-words performance. The follow-up research will enable us to establish an intact analysis of developmental pathways in L2 reading skills which will have practical contributions to the psycholinguistic theories of SLA.

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Appendix Ⅰ: Questionnaire

First Name: ________________ Date: _____________________

Surname: __________________

Age: _______________

Gender: ❑ Male ❑ Female

English Proficiency

1. How long have you been studied English?___________________

2. How long have you been living in the English speaking countries (e.g. USA, UK, Australia or others)?_______________ (If you have stayed in more than one country, please accumulate all the time together.)

3. What is your English proficiency test score for applying the postgraduate program?

TOEFL-iBT:	❑ under 78	❑ 79-95	❑96-120	or
IELTS:	❑ under 6.5	❑ 6.5-7	❑7.5-9.0	or
CPE:	❑ Grade C	❑ Grade B	❑Grade A	or
CAE:	❑ Grade C	❑ Grade B	❑Grade A	or

Appendix Ⅱ: Stimuli for experiment

	High-frequency				Low-frequency			
Regular	**Consistent**		**Inconsistent**		**Consistent**		**Inconsistent**	
	since	keep	key	tooth	barge	silk	pour	wreath
	board	point	food	gave	poach	brute	spoof	frost
	birth	name	home	here	shelf	starch	scare	pouch
	girl	plus	care	cloth	carve	greet	haste	beak
	wish	choice	plant	treat	dime	mince	fad	hive
Irregular	**Consistent**		**Inconsistent**		**Consistent**		**Inconsistent**	
	blood	both	tall	gross	blown	mild	grind	crow
	push	kind	heard	move	deaf	calf	mall	shove
	break	child	touch	youth	plaid	poll	fold	soot
	rough	please	come	gone	prey	hose	stalk	hearth
	show	friend	roll	son	cough	halt	tease	dough